10/578192
IAP12 Rec'd PCT/PTO 04 MAY 2006

DESCRIPTION

FURNACE AND DEGREASING METHOD

Technical Field

[0001] The present invention relates to furnaces and degreasing methods. The present invention particularly relates to a furnace which can prevent an article to be degreased from being cracked due to the abnormal combustion of gaseous organic decomposition products in such a manner that the concentration of gaseous oxygen in the furnace is maintained low and which can readily degrease the article at low cost in a short time and also relates to a degreasing method that is useful in readily obtaining a degreased article having no cracks at low cost in a short time.

Background Art

[0002] Ceramic materials containing organic substances (for example, organic binders or organic pore-forming agents) are used to manufacture ceramic products, for example, ceramic honeycomb structures, used in exhaust emission control systems for vehicles because such structures need to have high functions such as a function of supporting a catalyst and the ceramic materials have good molding properties. A molding (an article to be degreased) prepared by molding a ceramic material containing an organic substance usually needs to be degreased prior to firing the

molding at high temperature into a fired body such that the organic substance is removed from the article. In this operation, the organic substance (for example, polyvinyl alcohol or the like) contained in the article is decomposed and gasified by heating, whereby gaseous organic decomposition products (for example, methyl alcohol, acetaldehyde, and the like) are generated. Since the gaseous organic decomposition products each have an upper and lower explosive limit (for example, the upper and lower explosive limits of methyl alcohol are 7.3% and 19%, respectively, and those of acetaldehyde are 4.1% and 55%, respectively), there is a problem in that abnormal combustion such as explosion occurs during degreasing to cause cracks or flaws in the article if the concentration of the gaseous organic decomposition products is between the upper and lower explosive limits thereof. In order to solve the problem, a gas inlet is provided in a furnace and a dilution gas (for example, air) is introduced through the gas inlet such that the concentration of the gaseous organic decomposition products is reduced to be lower than the lower explosive limit and explosion is thereby prevented. In this technique, however, the above abnormal combustion cannot be prevented during degreasing because the concentration of the gaseous organic decomposition products in the furnace is high. Therefore, the article must be slowly heated and

degreased at low temperature for a long time; hence, this technique is inefficient.

[0003] In view of the foregoing circumstances, the following oven has been proposed: a microwave oven including a microwave heater, a furnace chamber for containing an article (which may be referred to as an article to be fired because it is fired in a subsequent step) to be degreased, and a carrier gas inlet tube for introducing a carrier gas which contains oxygen and which has an oxygen content less than that of air so as to reduce the combustion of an organic substance (see Patent Document 1).

Patent Document 1: Japanese Unexamined Patent Application Publication No. 2003-302166

[0004] The microwave oven disclosed in Patent Document 1, however, has a complicated configuration and is high in cost because the microwave oven needs to use the carrier gas having an oxygen content less than that of air so as to reduce the combustion of such an organic substance and needs to include the carrier gas inlet tube for introducing the carrier gas. Hence, the microwave oven is not necessarily satisfactory.

[0005] The present invention has been made in view of the foregoing circumstances. It is an object of the present invention to provide a furnace which can prevent an article

to be degreased from being cracked due to the abnormal combustion of gaseous organic decomposition products in such a manner that the concentration of oxygen gas in the furnace is maintained low and which can readily degrease the article at low cost in a short time and to provide a degreasing method that is useful in readily obtaining a degreased article having no cracks at low cost in a short time.

Disclosure of Invention

[0006] In order to achieve the above object, the inventors have made intensive investigations. As a result, the inventors have found that an article to be degreases is probably cracked as follows: gaseous organic decomposition products generated during degreasing are rapidly combusted in an atmosphere containing a large amount of gaseous oxygen. Furthermore, the inventors have found that the article can be prevented from being cracked in such a manner that a degreasing gas, used for degreasing, containing a small amount of gaseous oxygen is efficiently circulated in a system such that the gaseous organic decomposition products are removed from the system and the concentration of the gaseous organic decomposition products in the system and in such a manner that the article is degreased in an atmosphere containing a small amount of gaseous oxygen. The present invention is based on these findings. The present invention provides furnaces and degreasing methods below.

[0007] (1) A furnace (referred to as "a furnace according to a first aspect of the present invention" in some cases) includes a heating unit and a furnace body that can degrease an article to be degreased by heating the article with the heating unit, the article being disposed in the furnace body and containing an organic substance. The furnace body includes an outlet for discharging a degreasing gas containing a small amount of gaseous oxygen and a large amount of gaseous organic decomposition products generated in an internal section of the furnace body during the degreasing of the article and also includes an inlet for receiving a dilution gas, from outside, for reducing the concentration of the gaseous organic decomposition products in the furnace body to prevent the explosion of the gaseous organic decomposition products. The heating unit includes a first heater that can heat and degrease the article disposed in the furnace body and a second heater which heats the degreasing gas discharged from the outlet of the furnace body such that the gaseous organic decomposition products are removed and such that the degreasing gas is converted into a treatment gas containing a small amount of gaseous oxygen. The furnace further includes a treatment gas-introducing unit for introducing the treatment gas for dilution into the internal section of the furnace body from the second heater through the inlet and/or the first heater.

The treatment gas is introduced into the internal section of the furnace body from the inlet and/or the first heater in such a manner that the treatment gas is circulated through the internal section of the furnace body, the outlet, the second heater, the treatment gas-introducing unit, and the inlet and/or the first heater, whereby the concentration of the gaseous organic decomposition products in the internal section of the furnace body is reduced such that explosion is prevented, whereby the concentration of gaseous oxygen in the internal section of the furnace body is maintained low such that the article is prevented from being cracked due to the abnormal combustion of the gaseous organic decomposition products, and whereby the article can be degreased in a short time and then subjected to a subsequent firing step.

[0008] (2) A furnace (referred to as "a furnace according to a second aspect of the present invention" in some cases) includes a heating unit and a furnace body that can degrease an article to be degreased by heating the article with the heating unit, the article being disposed in the furnace body and containing an organic substance. The furnace body includes an outlet for discharging a degreasing gas containing a small amount of gaseous oxygen and a large amount of gaseous organic decomposition products generated in an internal section of the furnace body during the degreasing of the article and also includes an inlet for

receiving a dilution gas, from outside, for reducing the concentration of the gaseous organic decomposition products in the furnace body to prevent the explosion of the gaseous organic decomposition products. The heating unit includes a third heater which heats the degreasing gas discharged from the outlet of the furnace body such that the gaseous organic decomposition products are removed and such that the degreasing gas is converted into a treatment gas containing a small amount of gaseous oxygen. The furnace further includes a treatment gas-introducing unit for introducing the treatment gas for dilution into the internal section of the furnace body from the third heater through the inlet. The treatment gas is introduced into the internal section of the furnace body from the inlet in such a manner that the treatment gas is circulated through the internal section of the furnace body, the outlet, the third heater, the treatment gas-introducing unit, and the inlet, whereby the concentration of the gaseous organic decomposition products in the internal section of the furnace body is reduced such that explosion is prevented, whereby the concentration of gaseous oxygen in the internal section of the furnace body is maintained low such that the article is prevented from being cracked due to the abnormal combustion of the gaseous organic decomposition products, and whereby the article can be degreased in a short time and then subjected to a

subsequent firing step.

[0009] (3) The furnace according to Item (1) or (2) further includes a low-oxygen content gas-introducing unit for introducing a low-oxygen content gas, different in supply line from the treatment gas, into the internal section of the furnace body in addition to or instead of the treatment gas-introducing unit.

[0010] (4) In the furnace according to any one of Items (1) to (3), the organic substance contains at least one selected from the group consisting of polyvinyl alcohol, polyethylene glycol, starch, methylcellulose, carboxymethylcellulose, hydroxyethylcellulose, hydroxypropylmethylcellulose, polyethylene oxide, sodium polyacrylate, polyacrylamide, polyvinyl butyral, ethylcellulose, cellulose acetate, polyethylene, an ethylene-vinyl acetate copolymer, polypropylene, polystyrene, an acrylic resin, polyamide, glycerin, polyethylene glycol, and dibutyl phthalate.

[0011] (5) In the furnace according to any one of Items (1) to (4), the concentration of gaseous oxygen in the internal section of the furnace body is maintained at 0.5 to 17 volume percent using the treatment gas.

[0012] (6) In the furnace according to any one of Items (1) to (5), the first to third heaters are gas burners.

[0013] (7) In the furnace according to any one of Items

(1) to (6), the treatment gas-introducing unit includes a sealed pipe for communicatively connecting the second or third heater to the furnace body.

[0014] (8) The furnace according to any one of Items (1) to (7) further includes a heat-exchanging unit disposed between the second or third heater and the treatment gas-introducing unit and/or the low-oxygen content gas-introducing unit.

[0015] (9) In the furnace according to any one of Items (1) to (8), the article is porous and the percentage of the sum of the volumes of inflammable and/or non-volatile inorganic compounds remaining in the degreased article in the apparent volume of the degreased article [(the sum of the volumes of inflammable and/or non-volatile inorganic compounds remaining in the degreased article) / (the apparent volume of the degreased article) × 100] is preferably 5% to 60%.

[0016] (10) A degreasing method (referred to as "a degreasing method according to a third aspect of the present invention" in some cases) includes a step of degreasing an article to be degreased using a furnace including a heating unit and a furnace body by heating the article with the heating unit and a firing step subsequent to the degreasing step, the article being disposed in an internal section of the furnace body and containing an organic substance. The

furnace body includes an outlet for discharging a degreasing gas containing a small amount of gaseous oxygen and a large amount of gaseous organic decomposition products generated in the internal section of the furnace body during the degreasing of the article and also includes an inlet for receiving a dilution gas, from outside, for reducing the concentration of the gaseous organic decomposition products in the furnace body to prevent the explosion of the gaseous organic decomposition products. The heating unit includes a first heater that can heat and degrease the article disposed in the furnace body and a second heater which heats the degreasing gas discharged from the outlet of the furnace body such that the gaseous organic decomposition products are removed and such that the degreasing gas is converted into a treatment gas containing a small amount of gaseous oxygen. The furnace further includes a treatment gas-introducing unit for introducing the treatment gas for dilution into the internal section of the furnace body from the second heater through the inlet and/or the first heater. The treatment gas is circulated through the internal section of the furnace body, the outlet, the second heater, the treatment gas-introducing unit, and the inlet and/or the first heater, whereby the concentration of the gaseous organic decomposition products in the internal section of the furnace body is reduced such that explosion is prevented,

whereby the concentration of gaseous oxygen in the internal section of the furnace body is maintained low such that the article is prevented from being cracked due to the abnormal combustion of the gaseous organic decomposition products, and whereby the article can be degreased in a short time and then subjected to the subsequent firing step.

[0017] (11) In the degreasing method according to Item (10), the treatment gas is circulated through the internal section of the furnace body, the outlet, the second heater, the treatment gas-introducing unit, and the inlet without operating the first heater.

[0018] (12) A degreasing method (referred to as "a degreasing method according to a fourth aspect of the present invention" in some cases) includes a step of degreasing an article to be degreased using a furnace including a heating unit and a furnace body by heating the article with the heating unit and a firing step subsequent to the degreasing step, the article being disposed in an internal section of the furnace body and containing an organic substance. The furnace body includes an outlet for discharging a degreasing gas containing a small amount of gaseous oxygen and a large amount of gaseous organic decomposition products generated in the internal section of the furnace body during the degreasing of the article and also includes an inlet for receiving a dilution gas, from

outside, for reducing the concentration of the gaseous organic decomposition products in the furnace body to prevent the explosion of the gaseous organic decomposition products. The heating unit includes a third heater which heats the degreasing gas discharged from the outlet of the furnace body such that the gaseous organic decomposition products are removed and such that the degreasing gas is converted into a treatment gas containing a small amount of gaseous oxygen. The furnace further includes a treatment gas-introducing unit for introducing the treatment gas for dilution into the internal section of the furnace body from the third heater through the inlet. The treatment gas is circulated through the internal section of the furnace body, the outlet, the third heater, the treatment gas-introducing unit, and the inlet, whereby the concentration of the gaseous organic decomposition products in the internal section of the furnace body is reduced such that explosion is prevented, whereby the concentration of gaseous oxygen in the internal section of the furnace body is maintained low such that the article is prevented from being cracked due to the abnormal combustion of the gaseous organic decomposition products, and whereby the article can be degreased in a short time and then subjected to the subsequent firing step.

[0019] (13) The degreasing method according to any one of Items (10) to (12) further includes a low-oxygen content

gas-introducing unit for introducing a low-oxygen content gas, different in supply line from the treatment gas, into the internal section of the furnace body in addition to or instead of the treatment gas-introducing unit.

[0020] (14) In the degreasing method according to any one of Items (10) to (13), the organic substance contains at least one selected from the group consisting of polyvinyl alcohol, polyethylene glycol, starch, methylcellulose, carboxymethylcellulose, hydroxyethylcellulose, hydroxypropylmethylcellulose, polyethylene oxide, sodium polyacrylate, polyacrylamide, polyvinyl butyral, ethylcellulose, cellulose acetate, polyethylene, an ethylene-vinyl acetate copolymer, polypropylene, polystyrene, an acrylic resin, polyamide, glycerin, polyethylene glycol, and dibutyl phthalate.

[0021] (15) In the degreasing method according to any one of Items (10) to (14), the concentration of gaseous oxygen in the internal section of the furnace body is maintained at 0.5 to 17 volume percent using the treatment gas.

[0022] (16) In the degreasing method according to any one of Items (10) to (15), the first to third heaters are gas burners.

[0023] (17) In the degreasing method according to any one of Items (10) to (16), the treatment gas-introducing

unit includes a sealed pipe for communicatively connecting the second or third heater to the furnace body.

[0024] (18) The degreasing method according to any one of Items (10) to (17) further includes a heat-exchanging unit and/or catalyst disposed between the second or third heater and the treatment gas-introducing unit and/or the low-oxygen content gas-introducing unit.

[0025] (19) In the degreasing method according to any one of Items (10) to (18), the article is porous and the percentage of the sum of the volumes of inflammable and/or non-volatile inorganic compounds remaining in the degreased article in the apparent volume of the degreased article [(the sum of the volumes of inflammable and/or non-volatile inorganic compounds remaining in the degreased article) / (the apparent volume of the degreased article) × 100] is preferably 5% to 60%.

[0026] The present invention provides a furnace which can prevent an article to be degreased from being cracked due to the abnormal combustion of gaseous organic decomposition products in such a manner that the concentration of oxygen gas in the furnace is maintained low and which can readily degrease the article at low cost in a short time and a degreasing method that is useful in readily obtaining a degreased article having no cracks at low cost in a short time.

Brief Description of the Drawings

[0027]

[Fig. 1] Fig. 1 is a schematic view illustrating an embodiment (a furnace according to a first embodiment and a degreasing method according to a third embodiment) of the present invention.

[Fig. 2] Fig. 2 is a graph showing the relationship between the temperature and the change in weight of polyvinyl alcohol which has been sufficiently dried at 80° C and which is an organic substance, the relationship being obtained by heating polyvinyl alcohol at a rate of 5° C per minute in three types of gas streams.

[Fig. 3] Fig. 3 is a graph showing the relationship between the temperature and the heat generated from polyvinyl alcohol which has been sufficiently dried at 80° C and which is an organic substance, the relationship being obtained by heating polyvinyl alcohol at a rate of 5° C per minute in three types of gas streams.

[Fig. 4] Fig. 4 is a schematic view illustrating an embodiment (a furnace according to a second embodiment and the degreasing method of a fourth embodiment) of the present invention.

[Fig. 5] Fig. 5 is a schematic view illustrating an example (the furnace according to the first or second embodiment and the degreasing method of the third or fourth embodiment) of

the present invention.

Reference Numerals

[0028] 1 heating unit

2 furnace body

3 treatment gas-introducing unit

3a sealed pipe

3b circulating blower

3c damper

4 heat-exchanging unit

4a boiler

4b water spray

4c heat exchange efficiency adjuster

5 article to be degreased

6 degreasing gas

7 treatment gas

7a circulating gas

7b exhaust gas

7c steam

8 heat exchange gas

9 low-oxygen content gas-introducing unit

9a low-oxygen content gas

9b gaseous nitrogen-introducing member

9c gaseous nitrogen

10 furnace

11 first heater (furnace burner)

11a circulating-gas inlet of the furnace burner

11b fuel for the furnace burner

11c air for the furnace burner

12 second heater (afterburner)

12a afterburner combustion chamber

12b fuel for the afterburner

12c air for the afterburner

13 third heater

20 internal section of the furnace body

21 outlet

22 inlet

Best Mode for Carrying Out the Invention

[0029] Embodiments of the present invention will now be described with reference to the accompanying drawings.

[0030] Fig. 1 is a schematic view illustrating an embodiment (a furnace according to a first embodiment and a degreasing method according to a third embodiment) of the present invention. With reference to Fig. 1, the furnace according to the first embodiment includes a heating unit 1 and a furnace body 2 that can degrease an article 5 to be degreased by heating the article 5 with the heating unit 1, the article 5 being disposed in the furnace body 2 and containing an organic substance. The furnace body 2 includes an outlet 21 for discharging a degreasing gas 6 containing a small amount of gaseous oxygen and a large

amount of gaseous organic decomposition products generated in an internal section 20 of the furnace body during the degreasing of the article 5 and also includes an inlet 22 for receiving a dilution gas, from outside, for reducing the concentration of the gaseous organic decomposition products in the furnace body 2 to prevent the explosion of the gaseous organic decomposition products. The heating unit 1 includes a first heater 11 that can heat and degrease the article 5 disposed in the furnace body 2 and a second heater 12 which heats the degreasing gas 6 discharged from the outlet 21 of the furnace body 2 such that the gaseous organic decomposition products are removed (the gaseous organic decomposition products are not substantially present) and such that the degreasing gas 6 is converted into a treatment gas 7 containing a small amount of gaseous oxygen. The furnace further includes a treatment gas-introducing unit 3 for introducing the treatment gas 7 for dilution into the internal section of the furnace body 2 from the second heater 12 through the inlet 22 and/or the first heater 11. The treatment gas 7 is introduced into the internal section 20 of the furnace body through the inlet 22 and/or the first heater 11 in such a manner that the treatment gas 7 is circulated with, for example, a circulating blower 3b through the internal section 20 of the furnace body, the outlet 21, the second heater 12, the

treatment gas-introducing unit 3, and the inlet 22 and/or the first heater 11, whereby the concentration of the gaseous organic decomposition products in the internal section 20 of the furnace body is reduced such that explosion is prevented, whereby the concentration of gaseous oxygen in the internal section 20 of the furnace body is maintained low such that the article 5 is prevented from being cracked due to the abnormal combustion of the gaseous organic decomposition products, and whereby the article 5 can be degreased in a short time and then subjected to a subsequent firing step.

[0031] In this embodiment, when the treatment gas 7 for dilution is introduced (circulated) into the internal section 20 of the furnace body from the second heater 12 with the treatment gas-introducing unit 3, the treatment gas 7 may be introduced (circulated) thereinto through one or both of the inlet 22 and the first heater 11 (serving as circulation ports). In this case, conditions are preferably selected depending on the design of the furnace such that the temperature of the furnace can be readily controlled.

[0032] In this embodiment, the furnace preferably further includes a low-oxygen content gas-introducing unit 9 for introducing a low-oxygen content gas 9a, different in supply line from the treatment gas 7, into the internal section 20 of the furnace body in addition to or instead of the

treatment gas-introducing unit 3. In particular, when it is difficult to control the oxygen concentration to a desired value only by circulating the treatment gas 7, the low-oxygen content gas-introducing unit 9 is particularly effective in forcibly reducing the oxygen concentration. In addition to the treatment gas 7 (referred to as a heat exchange gas 8 in the case where a heat-exchanging unit 4 is used as described below), the following gas is referred to as "a circulating gas 7a" in some cases: an imaginary gas (in other words, gas repeatedly introduced into the internal section of the furnace body) including a gaseous mixture of the treatment gas 7 (the heat exchange gas 8) and the low-oxygen content gas 9a. Examples of the low-oxygen content gas 9a include an inert gas such as argon or nitrogen and a boiler exhaust gas. Examples of the low-oxygen content gas-introducing unit 9 include a unit that can introduce the low-oxygen content gas 9a, for example, a piping system connected to a boiler or a low-oxygen content gas generator. The low-oxygen content gas-introducing unit 9 may be used depending on the design of the furnace in addition to the treatment gas-introducing unit 3 as described above or instead of the treatment gas-introducing unit 3. The low-oxygen content gas-introducing unit 9, as well as the treatment gas-introducing unit 3, may be connected to one or both of the inlet 22 and the first heater 11.

[0033] The organic substance used in this embodiment is not particularly limited and may contain, for example, at least one selected from the group consisting of polyvinyl alcohol, polyethylene glycol, starch, methylcellulose, carboxymethylcellulose, hydroxyethylcellulose, hydroxypropylmethylcellulose, polyethylene oxide, sodium polyacrylate, polyacrylamide, polyvinyl butyral, ethylcellulose, cellulose acetate, polyethylene, an ethylene-vinyl acetate copolymer, polypropylene, polystyrene, an acrylic resin, polyamide, glycerin, polyethylene glycol, and dibutyl phthalate each serving as an organic binder. When the article 5 described below in detail is porous, the organic substance may contain a pore-forming agent in addition to such an organic binder. The pore-forming agent contains natural organic particles made of starch or rice hull, hydrocarbon particles made of paraffin with a molecular weight of 1000 or less, or particles made of an organic ester with a molecular weight of 1000 or less. These materials are decomposed by combustion, whereby the gaseous organic decomposition products are generated. The gaseous organic decomposition products are, for example, methyl alcohol, acetaldehyde, methyl formate, carbon dioxide, carbon monoxide, water, and tar.

[0034] Fig. 2 shows the relationship between the temperature and the change in weight of polyvinyl alcohol

which has been sufficiently dried at 80° C and which is contained in the organic substance, the relationship being obtained by heating polyvinyl alcohol at a rate of 5° C per minute in three types of gas streams. Fig. 3 shows the relationship between the temperature and the heat generated from polyvinyl alcohol.

[0035] As is clear from Fig. 3, the heat generated from polyvinyl alcohol heated in a gas stream containing 20% oxygen (80% nitrogen and 20% oxygen) is 95. The heat generated from polyvinyl alcohol heated in a gas stream containing 10% oxygen (90% nitrogen and 10% oxygen) is 32. Furthermore, the heat generated from polyvinyl alcohol heated in a gas stream containing no oxygen (100% nitrogen) is about 19. If a graph (not shown) in which the horizontal axis represents the oxygen content and the vertical axis represents the generated heat is made on the basis of the above data, the graph shows that the heat generated from polyvinyl alcohol heated in a gas stream containing 15% oxygen is 45 and the heat generated from polyvinyl alcohol heated in a gas stream containing 1% oxygen is 20. That is, the heat generated from polyvinyl alcohol heated in the gas stream containing 15% oxygen is half or less of the heat generated from polyvinyl alcohol heated in the gas stream containing 20% oxygen. This means that the gaseous organic decomposition products are hardly combusted but are

vaporized. As shown in Fig. 2, the weight of a carbonaceous residue obtained by heating polyvinyl alcohol to 400°C or higher in the gas stream containing no oxygen (100% nitrogen) is about 8% of that of unheated polyvinyl alcohol. If the residue is heated to a higher temperature, the residue will be completely decomposed.

[0036] Since the furnace has the above configuration, the degreasing time needed for the furnace is about half of that needed for known one.

[0037] The article used in this embodiment is not particularly limited and may be, for example, a ceramic structure. A ceramic material for forming the article is not particularly limited and may contain oxide ceramic powder, for example, alumina powder, and one to 20 mass percent of an organic compound.

[0038] In this embodiment (as well as second to fourth embodiments of the present invention), the article 5 is preferably porous and the percentage of the sum of the volumes of inflammable and/or non-volatile inorganic compounds remaining in the degreased article 5 in the apparent volume of the degreased article 5 [(the sum of the volumes of inflammable and/or non-volatile inorganic compounds remaining in the degreased article) / (the apparent volume of the degreased article) × 100] is preferably 5% to 60%, more preferably 5% to 40%, and further

more preferably 5% to 20%, because the furnace exhibits advantages. That is, when the article 5 is porous, the content of the organic substance containing the organic binder and the organic pore-forming agent in the article 5 is greater than that of the organic substance in an ordinary article and the diffusion of heat and gas in the article 5 is higher than that in the ordinary article; hence, abnormal combustion hardly occurs in the article 5. Furthermore, since the article 5 has low material strength, the article 5 is vulnerable to a stress caused during degreasing; hence, the article 5 is preferably porous because the furnace exhibits significant advantages. The term "inflammable and/or non-volatile inorganic compounds" does not cover any carbonaceous material such as graphite and the term "the apparent volume of the article 5 to be degreased" covers the volumes (volumetric capacities) of microcavities such as small closed cells, open cells, and grooves but does not cover the volumes (volumetric capacities) of macrocavities, such as large closed cells, open cells, and grooves, having an inradius of 10 mm or more.

[0039] The heating unit 1 (the first heater 11 and the second heater 12) used in this embodiment is not particularly limited and may be a fuel oil burner, a gas burner, an electric heater, a regenerative burner, or the like. The second heater 12 may use a catalytic combustion

method in which an oxidation catalyst containing platinum or the like and the direct combustion method are used in combination. The catalytic combustion method is useful in more efficiently burning off the gaseous organic decomposition products and effective in controlling the heating temperature of the degreasing gas to be lower as compared to a method (the direct combustion method) using no catalyst (the heating temperature of the degreasing gas can be controlled to be 300° C to 350° C depending on components of the degreasing gas). Only the heating unit 1 (the first heater 11 and the second heater 12) may be used and another heating unit may be used in addition to the heating unit 1.

[0040] The treatment gas-introducing unit 3 used in this embodiment is not particularly limited and preferably includes a sealed pipe 3a for communicatively connecting the second heater 12 to the furnace body 2. Alternatively, the treatment gas-introducing unit 3 may include a duct made of brick or a heat insulator. The treatment gas 7 (the circulating gas 7a) can be circulated with the circulating blower 3b.

[0041] In this embodiment, the furnace preferably further includes the heat-exchanging unit 4 which is, for example, a heat exchanger and which is disposed between the second heater 12 and the treatment gas-introducing unit 3. In this configuration, the treatment gas 7 passing through the heat-

exchanging unit 4 turns into the heat exchange gas 8 having a temperature lower than that of the treatment gas 7. The heat exchange gas 8 is introduced into the inlet 22. According to this configuration, heat can be recovered from the degreasing gas 6, which is released from a known furnace. The recovered heat can be used in a steam boiler or the like. Furthermore, an atmosphere in the internal section 20 of the furnace body can be controlled in such a manner that the temperature and flow rate of the treatment gas 7 (the circulating gas 7a) introduced into the internal section 20 of the furnace body from the inlet 22 are controlled with the heat-exchanging unit 4.

[0042] Examples of the heat-exchanging unit 4 include a device for directly spraying water into a stream of the treatment gas 7 to cool the treatment gas 7. If such a device is used, sprayed water is converted into steam, which is mixed with the treatment gas. Therefore, the temperature of the treatment gas 7 is not only decreased (heat is recovered) but the content of oxygen in the treatment gas 7 is reduced.

[0043] The compositions, oxygen contents, and temperatures of these gases will now be comparatively described. The degreasing gas 6 (of which the composition and temperature are comparable to those of gas in the internal section 20 of the furnace body) contains a large

amount of the gaseous organic decomposition products and has a low oxygen content and a medium temperature. The treatment gas 7 hardly contains the gaseous organic decomposition products and has a low oxygen content and a high temperature. The heat exchange gas 8 hardly contains the gaseous organic decomposition products and has a low oxygen content and a low temperature. In particular, the degreasing gas 6 has an organic decomposition product content of one to 15 volume percent, an oxygen content of 0.5 to 17 volume percent, and a temperature of 100° C to 400° C. The degreasing time to remove the organic substance is 50% of that of a conventional furnace. The treatment gas 7 has an oxygen content of 0.5 to 17 volume percent. The treatment gas 7 heated with the second heater (afterburner) has a temperature of 500° C to 900° C. The heat exchange gas 8 preferably has an oxygen content of 0.5 to 17 volume percent and a temperature that is 1° C to 100° C higher than the temperature of the furnace during degreasing.

[0044] In this embodiment, since the treatment gas 7 (the circulating gas 7a) is circulated, the concentration of gaseous oxygen in the internal section 20 of the furnace body can be maintained at 0.5 to 17 volume percent.

[0045] The operation of the furnace of this embodiment will now be described. With reference to Fig. 1, the article (ceramic molding) 5, containing the organic

substance, to be degreased is disposed in the internal section 20 of the furnace body made of a heat insulator. The furnace is heated with the first heater (burner) 11. An atmosphere in the furnace body 2 is gradually heated by the heat from the burner 11. The gaseous organic decomposition products are generated from the article (ceramic molding) 5 at the point of time when the furnace temperature exceeds 100° C. The gaseous organic decomposition products are fed to the second heater (afterburner) 12 through the outlet 21 and treatment gas-introducing unit (duct) 3 of the furnace body 2 and then combusted. The treatment gas 7 heated to a high temperature by the combustion is introduced into the heat-exchanging unit (heat exchanger) 4 and then cooled into the heat exchange gas 8 with a temperature close to that of the furnace. The heat exchange gas 8 is fed through the inlet 22 and/or the first heater (burner) 11 disposed in the furnace body 2. The low-oxygen content gas 9a different in supply line from the treatment gas 7 is may be fed with the low-oxygen content gas-introducing unit 9 through the internal section 20 of the furnace body and/or the first heater (burner) 11 in addition to or instead of the treatment gas 7 (the heat exchange gas 8). Whether the treatment gas 7 (the heat exchange gas 8 and/or the low-oxygen content gas 9a) is fed to one or both of the inlet 22 and the first heater (burner) 11 is preferably selected or

determined by a switching operation or the like on the basis of the design concept. Furthermore, whether one or both of the treatment gas-introducing unit 3 (the treatment gas 7 and/or the heat exchange gas 8) and the low-oxygen content gas-introducing unit 9 (the low-oxygen content gas 9a) are operated is preferably selected or determined by a switching operation or the like on the basis of the design concept (for example, the flow rate of the circulating gas 7a is controlled).

[0046] The flow rate of the circulating gas 7a is preferably large such that the gaseous organic decomposition products generated in the furnace can be efficiently discharged through the outlet 21. If the volume of the furnace body 2 is supposed to be 10, the flow rate of the circulating gas 7a is preferably one to 100 per minute and more preferably ten to 50 per minute. When the flow rate thereof is less than one per minute, it takes a long time to discharge the gaseous organic decomposition products 6. When the flow rate thereof is more than 100 per minute, a furnace having a large size needs to include a blower, burner, and heat exchanger having a large size and a large capacity such that the flow rate and temperature of the circulating gas 7a are maintained at desired values. This is inefficient.

[0047] A degreasing method according to an embodiment

(the third embodiment) of the present invention includes a step of degreasing an article 5 to be degreased using a furnace 10, similar to that shown in Fig. 1, including a heating unit 1 and a furnace body 2 by heating the article 5 with the heating unit 1 and a firing step subsequent to the degreasing step, the article 5 being disposed in an internal section 20 of the furnace body and containing an organic substance. The furnace body 2 includes an outlet 21 for discharging a degreasing gas 6 containing a small amount of gaseous oxygen and a large amount of gaseous organic decomposition products generated in the internal section 20 of the furnace body during the degreasing of the article 5 and also includes an inlet 22 for receiving a dilution gas, from outside, for reducing the concentration of the gaseous organic decomposition products in the furnace body 2 to prevent the explosion of the gaseous organic decomposition products. The heating unit 1 includes a first heater 11 that can heat and degrease the article 5 disposed in the furnace body 2 and a second heater 12 which heats the degreasing gas 6 discharged from the outlet 21 of the furnace body 2 such that the gaseous organic decomposition products are removed and such that the degreasing gas 6 is converted into a treatment gas 7 containing a small amount of gaseous oxygen. The furnace further includes a treatment gas-introducing unit 3 for introducing the treatment gas 7

(a circulating gas 7a) for dilution into the internal section 20 of the furnace body 2 from the second heater 12 through the inlet 22 and/or the first heater 11. The treatment gas 7 (the circulating gas 7a) is circulated through the internal section 20 of the furnace body, the outlet 21, the second heater 12, the treatment gas-introducing unit 3, and the inlet 22 and/or the first heater 11, whereby the concentration of the gaseous organic decomposition products in the internal section 20 of the furnace body is reduced such that explosion is prevented, whereby the concentration of gaseous oxygen in the internal section 20 of the furnace body is maintained low such that the article 5 is prevented from being cracked due to the abnormal combustion of the gaseous organic decomposition products, and whereby the article 5 can be degreased in a short time and then subjected to the subsequent firing step.

[0048] In this embodiment, the furnace (the furnace of the first embodiment) shown in Fig. 1 can be used. The furnace of the first embodiment includes the gas burner as described above. The furnace of this embodiment, as well as the furnace of the first embodiment, may include a gas burner. Alternatively, the furnace of this embodiment may be an electric furnace which can supply a sufficient amount of the circulating gas and control the concentration of oxygen therein. The furnace of this embodiment may be a

hybrid type of furnace including an electric heater and a gas burner (a furnace described below in the fourth embodiment of the present invention is as well as the furnace of this embodiment).

[0049] In this embodiment, the article 5 may be degreased in such a manner that the treatment gas 7 (the circulating gas 7a) is circulated through the internal section 20 of the furnace body, the outlet 21, the second heater 12, the treatment gas-introducing unit 3, and the inlet 22 without operating the first heater 11 of the furnace according to the first embodiment. In order to maintain the temperature of the internal section of the furnace body at 400°C or less, a heat-exchanging unit 4 and/or a low-oxygen content gas-introducing unit 9 is preferably operated. When the heat-exchanging unit 4 includes a boiler, the heat-exchanging unit 4 preferably includes a heat exchange efficiency adjuster which can adjust the level of water in a vessel included in the boiler and which can adjust the temperature of gas discharged from an outlet of the boiler to control the temperature of the internal section of the furnace body. According to this configuration, the same advantages as those of a degreasing method according to the fourth embodiment can be obtained. That is, degreasing can be performed readily and efficiently.

[0050] Fig. 4 is a schematic view illustrating an

embodiment (a furnace according to a second embodiment and the degreasing method of the fourth embodiment) of the present invention. With reference to Fig. 4, the furnace of this embodiment (the second embodiment) includes a heating unit and a furnace body 2 that can degrease an article 5 to be degreased by heating the article 5 with the heating unit, the article 5 being disposed in an internal section 20 and containing an organic substance. The furnace body 2 includes an outlet 21 for discharging a degreasing gas 6 containing a small amount of gaseous oxygen and a large amount of gaseous organic decomposition products generated in the internal section 20 of the furnace body during the degreasing of the article 5 and also includes an inlet 22 for receiving a dilution gas, from outside, for reducing the concentration of the gaseous organic decomposition products in the furnace body 2 to prevent the explosion of the gaseous organic decomposition products. The heating unit includes a third heater 13 (the third heater 13 may be as well as the second heater 12 included in the furnace of the first embodiment) which heats the degreasing gas 6 discharged from the outlet 21 of the furnace body 2 such that the gaseous organic decomposition products are removed and such that the degreasing gas 6 is converted into a treatment gas 7 containing a small amount of gaseous oxygen. The furnace further includes a treatment gas-introducing

unit 3 for introducing the treatment gas 7 (a circulating gas 7a) for dilution into the internal section of the furnace body 2 from the third heater 13 through the inlet 22. The treatment gas 7 is introduced into the internal section 20 of the furnace body from the inlet 22 in such a manner that the treatment gas 7 is circulated through the internal section 20 of the furnace body, the outlet 21, the third heater 13, the treatment gas-introducing unit 3, and the inlet 22, whereby the concentration of the gaseous organic decomposition products in the internal section 20 of the furnace body is reduced such that explosion is prevented, whereby the concentration of gaseous oxygen in the internal section 20 of the furnace body is maintained low such that the article 5 is prevented from being cracked due to the abnormal combustion of the gaseous organic decomposition products, and whereby the article 5 can be degreased in a short time and then subjected to a subsequent firing step.

[0051] As is clear from Fig. 4, the difference between the furnace of this embodiment (the furnace of the second embodiment) and the furnace of the first embodiment is that the furnace of this embodiment does not include the first heater 11, shown in Fig. 1, included in the furnace of the first embodiment and the temperature of the furnace body is adjusted with the third heater 13, a heat-exchanging unit 4, a low-oxygen content gas-introducing unit 9, and/or the like.

The furnace of this embodiment may have substantially the same configuration as that of the furnace of the first embodiment except the above difference. According to this configuration, degreasing can be performed readily and efficiently.

[0052] The degreasing method according to an embodiment (the third embodiment) of the present invention includes a step of degreasing an article 5 to be degreased using a furnace 10, similar to that shown in Fig. 4, including a heating unit 1 and a furnace body 2 by heating the article 5 with the heating unit 1 and a firing step subsequent to the degreasing step, the article 5 being disposed in an internal section 20 of the furnace body and containing an organic substance. The furnace body 2 includes an outlet 21 for discharging a degreasing gas 6 containing a small amount of gaseous oxygen and a large amount of gaseous organic decomposition products generated in the internal section 20 of the furnace body during the degreasing of the article 5 and also includes an inlet 22 for receiving a dilution gas, from outside, for reducing the concentration of the gaseous organic decomposition products in the furnace body 2 to prevent the explosion of the gaseous organic decomposition products. The heating unit includes a third heater 13 which heats the degreasing gas 6 discharged from the outlet 21 of the furnace body 2 such that the gaseous organic

decomposition products are removed and such that the degreasing gas 6 is converted into a treatment gas 7 containing a small amount of gaseous oxygen. The furnace further includes a treatment gas-introducing unit 3 for introducing the treatment gas 7 (a circulating gas 7a) for dilution into the internal section 20 of the furnace body 2 from the third heater 13 through the inlet 22. The treatment gas is circulated through the internal section 20 of the furnace body, the outlet 21, the third heater 13, the treatment gas-introducing unit 3, and the inlet 22, whereby the concentration of the gaseous organic decomposition products in the internal section 20 of the furnace body is reduced such that explosion is prevented, whereby the concentration of gaseous oxygen in the internal section 20 of the furnace body is maintained low such that the article 5 is prevented from being cracked due to the abnormal combustion of the gaseous organic decomposition products, and whereby the article 5 can be degreased in a short time and then subjected to the subsequent firing step.

[0053] As is clear from Fig. 4, the difference between the degreasing method of this embodiment (the degreasing method of the fourth embodiment) and the degreasing method of the third embodiment is that the furnace (including no heater 11) used in the degreasing method of this embodiment is different from the furnace, used in the degreasing method

of the third embodiment, including the first heater 11 shown in Fig. 1 and the temperature of the furnace body is adjusted with the third heater 13, a heat-exchanging unit 4, a low-oxygen content gas-introducing unit 9, and/or the like. The degreasing method of this embodiment may be substantially the same as the degreasing method of the first embodiment except the above difference. According to this method, degreasing can be performed readily and efficiently.

[0054] In the embodiments (the furnace of the first or second embodiment and the degreasing method of the third or fourth embodiment) of the present invention, the degreasing temperature (the final degreasing temperature) is preferably adjusted to an optimum value (for example, 350°C to 500°C) depending on the type of each organic substance, the shape and density of each article (molding), and/or the like. The firing temperature of each firing step performed subsequently to each degreasing step as required is preferably adjusted to 1200°C to 2000°C.

Examples

[0055] The present invention will be further described in detail with reference to Examples. The present invention is not limited to Examples.

[0056] In Examples, a furnace 10, shown in Fig. 5, including the following components was used: a furnace body 2 with a volume of 0.5 m^3; a heating unit including a first

heater (furnace burner) 11 with a capacity of 100 kW and a second heater (afterburner) 12 with a capacity of 50 kW; a treatment gas-introducing unit including a sealed pipe 3a, a circulating blower 3b, and a damper 3c; a heat-exchanging unit including a boiler 4a (including a heat exchange efficiency adjuster 4c) having a thermal capacity of 25 kW and a water flow rate of 1 L/min and a water spray 4b with a water flow rate of 0.5 L/min; and a low-oxygen content gas-introducing unit including a gaseous nitrogen-introducing member 9b (gaseous nitrogen 9c). In Fig. 5, reference numeral 11a represents a circulating-gas inlet of the furnace burner, reference numeral 11b represents a fuel for the furnace burner, reference numeral 11c represents air for the furnace burner, reference numeral 12a represents an afterburner combustion chamber, reference numeral 12b represents a fuel for the afterburner, reference numeral 12c represents air for the afterburner, reference numeral 5 represents articles to be degreased, reference numeral 6 represents a degreasing gas, reference numeral 7 represents a treatment gas, reference numeral 7a represents a circulating gas, reference numeral 7b represents an exhaust gas, reference numeral 21 represents an outlet, and reference numeral 22 represents an inlet.

[0057] An alumina slurry containing ten mass percent of starch serving as a pore-forming agent and the following

compounds each serving as an organic binder was prepared: two mass percent of polyvinyl alcohol, two mass percent of polyethylene glycol, two mass percent of methylcellulose, two mass percent of carboxymethylcellulose, and two mass percent of hydroxyethylcellulose. The sum of the contents of these compounds was ten mass percent. The alumina slurry was dried and then formed into particles, which were formed into 55 porous moldings. The moldings had a diameter of 50 mm and a height of 100 mm and contained about 50 volume percent of an inflammable or non-volatile inorganic compound to be present in the degreased moldings.

[0058] (Example 1)

Five of the moldings that were articles 5 to be degreased were placed in the furnace 10. Among elements (units) included in the furnace 10, the following units (operated units) were operated as shown in Table 1: the heating unit including the first heater (furnace burner) 11 with a capacity of 100 kW and the second heater (afterburner) 12 with a capacity of 50 kW and the heat-exchanging unit including the boiler 4a (including the heat exchange efficiency adjuster 4c) having a thermal capacity of 25 kW and a flow rate of 1 L/min and a water spray with a flow rate of 0.5 L/min. The circulating gas 7a was circulated. In Table 1, the symbol A represents the operated units and the symbol B represents the units not

operated. The type of the heat-exchanging unit is shown in Table 1 if the heat-exchanging unit was operated. The five moldings were heated to 500° C over a period of 25 hours at a rate of 20° C/h in such a manner that air was supplied to the furnace burner at 0.5 Nm^3/min at a furnace temperature of 200° C, the circulating gas was circulated at 1.0 Nm^3/min, and the oxygen concentration was maintained at 10 volume percent, whereby the moldings were degreased. Table 2 shows heating conditions of the moldings. The degreased moldings had no cracks.

[0059] (Examples 2 to 8)

Five of the moldings were degreased in each Example in the same manner as that described in Example 1 except operated units shown in Table 1 and heating conditions shown in Table 2. The degreased moldings had no cracks. In Example 6, the gaseous nitrogen-introducing member 9b (gaseous nitrogen 9c) was operated. In Example 7, the heat exchange efficiency adjuster 4c was operated in addition to the boiler 4a such that the temperature of the furnace was controlled with the heat exchange efficiency adjuster 4c. The heat exchange efficiency adjuster 4c could control the temperature of gas discharged from the boiler 4a by adjusting the level of water in the boiler 4a. In Example 8, the water spray 4b included in the heat-exchanging unit was operated instead of the boiler 4a. In Example 7, the

furnace was operated without operating the first heater (furnace burner) 11. A furnace (similar to the furnace, shown in Fig. 4, described in the second embodiment) including no first heater (furnace burner) 11 may be operated under the same conditions as those described in Example 7.

[0060] (Comparative Examples 1 to 3)

Five of the moldings were degreased in each Comparative Example in the same manner as that described in Example 1 except operated units shown in Table 1 and heating conditions shown in Table 2. In Comparative Examples 1 to 3, the furnace was operated without circulating the circulating gas 7a and without operating the heat-exchanging unit (the boiler 4a) and the low-oxygen content gas-introducing unit (the gaseous nitrogen-introducing member 9b). The following moldings were broken into pieces as if the moldings were exploded: four of the moldings degreased in Comparative Example 1 and three of the moldings degreased in Comparative Example 2. The other one (or two) thereof was broken into two large pieces. In Comparative Example 3, the moldings were degreased for a long time at low temperatures (the moldings were heated to 500° C over a period of 95 hours at a rate of 5° C/h); hence, the degreased moldings had no cracks. However, the procedure of Comparative Example 3 is not efficient.

[0061] (Table 1)

	Circulating Gas	Furnace Burner	After-burner	Heat-exchanging Unit	Gaseous nitrogen-introducing Member
Example 1	A	A	A	A (Boiler)	B
Example 2	A	A	A	A (Boiler)	B
Example 3	A	A	A	A (Boiler)	B
Example 4	A	A	A	A (Boiler)	B
Example 5	A	A	A	A (Boiler)	B
Example 6	A	A	A	A (Boiler)	A
Example 7	A	B	A	A (Boiler and Efficiency Adjuster)	B
Example 8	A	A	A	A (Water Spray)	B
Comparative Example 1	B	A	A	B	B
Comparative Example 2	B	A	A	B	B
Comparative Example 3	B	A	A	B	B

[0062] (Table 2)

	Flow Rate (Nm^3/min)				Oxygen Concentration (%)	Heating Rate (°C/h)	Time to reach 500°C
	Air for Furnace Burner	Circulating Gas	Steam	Gaseous Nitrogen			
Example 1	0.5	1.0	-	-	10	20	23.8
Example 2	0.8	0.7	-	-	15	10	47.5
Example 3	1.0	0.5	-	-	17	10	47.5
Example 4	0.3	1.3	-	-	5	25	19.0
Example 5	0.1	1.4	-	-	1	50	9.5
Example 6	0.1	0.7	-	0.8	0.5	50	9.5
Example 7	0.3	1.2	-	-	10	20	23.8
Example 8	0.5	0.5	0.5	-	5	25	19.0
Comparative Example 1	1.5	-	-	-	21	20	23.8
Comparative Example 2	1.5	-	-	-	21	10	47.5
Comparative Example 3	1.5	-	-	-	21	5	95.0

Industrial Applicability

[0063] A furnace and degreasing method according to the present invention are useful in manufacturing various ceramic products and particularly useful in manufacturing ceramic products formed using a ceramic material containing an organic substance.